REMARKS/ARGUMENTS

Claims 1 and 18 have been amended to further define the process chamber as being enclosed by a solid wall and having an inlet for a process stream and an outlet for a process effluent. Support for these amendments is found on page 7 of the specification, lines 5-9, and in Figs. 1-9, which show various process chambers, all of which are enclosed by solid walls, and all of which have inlets for a process stream and outlets for process effluent. Claims 5 and 20 have been amended to recite the temperature range and residence time of the thermal cracking reaction to produce olefins. Support for the amendments is found on page 14 of the specification, lines 12-14.

The above amendments relate to the new grounds for rejection raised for the first time in the current Office action. The amendments form part of the response to the new grounds of rejection and are believed to place the application in better condition for allowance or appeal. Hence, their entry is respectfully requested.

Applicant will now address the points raised in the Examiner's Detailed Action in the same general order as they are presented in the Action.

Claim Rejections – 35 U.S.C §102

The rejection of claims 1-7, 14-18 and 20-24 under 35 U.S.C. § 102(b) as being anticipated by Ruhl (EP 0 450 872) is respectfully traversed.

A critical structural feature of the flameless distributed combustion process heater of the invention is that the plurality of fuel nozzles in the fuel conduit be distributed along substantially the entire length of the oxidation chamber. Since the oxidation chamber is in a heat exchange relationship with the process chamber, the distribution of the fuel nozzles along substantially the entire length of the oxidation chamber allows the provision of a controlled heat by the oxidation chamber to the process chamber at a desired temperature profile and rate of flux, sufficient to complete the endothermic chemical reaction being conducted in the process chamber. This results in improved conversions, product yields, byproduct reduction, etc.

Contrary to the statement on page 2 of the current Office action, the plurality of fuel nozzles (64) in Fig. 4 of Ruhl, is not "distributed along substantially the entire length of said oxidation chamber (30, 68)". All of perforations or holes 64 in Fig. 4 of Ruhl are spaced only in burner zone 68 which represents only a minor portion (appears to be roughly 20%) of the overall length of combustion tube (oxidation chamber) 30. There are no perforations in the upper portion or the lower portion of combustion tube 30. This uneven distribution of fuel nozzles in the

oxidation chamber will result in an uneven temperature distribution in combustion tube 30, with the temperature in "burner zone" 68 of the combustion tube 30 being greater than the temperature in the upper or lower portions of combustion tube. This conclusion is supported by the statement in Ruhl on page 5, lines 55-56, that plug 66, which is at the upper end of fuel tube 60, "need not resist very hot temperatures and thus could be made of graphite or heat resistant organic cement". Based on the location of the perforations in fuel tube 60 in Fig. 4 and the foregoing statement about plug 66, it is clear that Ruhl does not disclose "distributed' combustion, nor would the apparatus in Ruhl be able to achieve the variety of temperature profiles in the process chamber that are achievable in Applicant's apparatus.

Since the fuel nozzles (perforations 64) in Ruhl are not distributed along substantially the entire length of the oxidation chamber, Ruhl does not produce "flameless, distributed combustion throughout said oxidation chamber (Fig. 4)" as stated at the bottom of page 2 of the current Office action. "Distributed combustion throughout the oxidation chamber" requires fuel nozzles to be spaced along substantially the entire length of the oxidation chamber, which is clearly not taught or suggested in Fig. 4 of Ruhl.

Applicant agrees that claims should be given the broadest reasonable interpretation in view of the specification. However, Applicant submits there is absolutely no reasonable basis to define the oxidation chamber in Ruhl as being only that small portion of combustion tube 30 surrounding perforations 64. Clearly the entire combustion tube 30 is the oxidation chamber in the reaction apparatus in Fig.4 of Ruhl. Combustion tube 30 in the apparatus of Fig.4 of Ruhl runs the full length of the reactor. There are no walls or barriers dividing combustion tube 30 into separate sections or compartments. Oxidant and fuel are free to mix and combust anywhere in combustion tube 30. Hence, it is unreasonable to define the oxidation chamber in Ruhl as being only that small portion of combustion tube 30 surrounding perforations 64. Clearly the entire combustion tube 30 is the oxidation chamber in the reaction apparatus in Fig.4 of Ruhl.

Since the fuel nozzles (perforations 64) in Ruhl are distributed over only a small portion (about 20%) of combustion tube 30 (i.e., in burner zone 68), Ruhl cannot reasonably be said to meet the limitation in each of the present claims that the fuel nozzles be distributed along substantially the entire length of the oxidation chamber.

Therefore, the rejection of claims 1-7, 14-18 and 20-24 on the basis of anticipation by Ruhl is untenable and should be withdrawn, which action is respectfully requested.

Claims 17 and 24 are not anticipated by Ruhl for the additional reason that Ruhl does not disclose preheating the oxidant by heat exchange with effluent from the process chamber. Instead, Ruhl appears to contemplate preheating the oxidant using a conventional commercial

preheater. See page 5, lines 44-45, where it is stated: "Although no preheater is illustrated, such devices are known in the art and are commercially available". This statement certainly does not anticipate preheating oxidant using effluent from a process chamber.

In paragraph 11 of the present Office action, the Examiner makes the argument that Ruhl does anticipate claims 17 and 24 because in Fig. 4 the oxidant in oxidant manifold 42 is preheated by heat exchange (heat being transferred by steel plate 16) with the reaction products produced in the process chamber and traveling towards the outlet 24. Applicant does not disagree that some minimal heat exchange might take place between the incoming oxidant in manifold 42 and the reaction products in the process chamber through steel plate 16. However, this disclosure does not anticipate claims 17 and 24, because these claims cover the embodiment wherein the oxidant is preheated with effluent from the process chamber. As known to one skilled in the art, "effluent" is the gas or liquid which emerges from a pipe or similar outlet. The effluent from the process chamber in Ruhl is the gas which emerges from outlet 24. Ruhl does not disclose utilizing this effluent stream for preheating the oxidant. Whatever minimal inherent preheating of the oxidant occurs through steel plate 16 is the result of heat exchange with reaction products in the reactor. There is no disclosure using effluent from the process chamber for preheating the oxidant. Hence, claims 17 and 24 are not anticipated by Ruhl for this reason, as well as those discussed above.

Since Applicant is relying on structural limitations to distinguish the present apparatus over Ruhl (e.g., that the plurality of fuel nozzles be distributed along substantially the entire length of the oxidation chamber and that the flameless distributed combustion process heater be configured so that the oxidant is preheated by heat exchange with effluent from the process chamber), and not on statements made in the preamble, nor the manner in which the apparatus is intended to be used, nor the contents thereof, the rationale of *In re Otto*, 312 F.2d 937, 938, 136 USPQ 458, 459 (CCPA 1963), etc., *Ex parte Masham*, 2 USPQ2d, 1647 (Bd. Pat. App. & Inter. 1987) and *Ex Parte Thibault*, 164 USPQ 666, 667 (Bd. App. 1969) does not apply.

The rejection of claims 1-5, 16-18, 20-21 and 24 under 35 U.S.C. § 102(b) as being anticipated by Mikus (USP 5, 255,742) is respectfully traversed.

On page 8 of the current Office Action it is stated that Mikus discloses:

> " - a process chamber (1) in a heat exchange relationship with the oxidation chamber (Fig. 2-3), whereby a controlled heat flux is provided to the process chamber at a sufficiently high rate to complete the endothermic process being conducted therein (C1/L13-44)".

Applicant does not believe this statement is supported by a reasonable reading of the Mikus reference. Item (1) in Figs. 2-3 of Mikus does not represent a "process chamber". Instead, it represents the "formation to be heated" (Mikus, col. 7, line 45). A "formation" is a naturally occurring, geological structure located hundreds or even thousands of feet underground, that basically consists of rocky materials which may contain oil and water trapped in the pores of the formation rock. Injection of heat into the formation causes thermal expansion of the water and oil trapped within the pores of the formation rock causing it to fracture. The hydrocarbons migrate through the small fractures created by the expansion and vaporization of oil and water. (See Mikus col.1, lines 24-36).

Applicant submits it is unreasonable to refer to this fractured, porous structure as a "process chamber". The customary meaning of the term "process chamber" in the chemical process arts is an enclosed space surrounded by walls or other solid structure in which a chemical process is performed. A fractured porous underground formation cannot reasonably be construed to be a "process chamber" as this term is used in the present claims.

However, in order to expedite allowance of the claims, claims 1 and 18 have been amended to provide that the process chamber be "enclosed by a solid wall, having an inlet for a process stream and an outlet for process effluent".

These amendments clearly distinguish the instantly claimed apparatus from Mikus in that the formation rock in Mikus is porous to begin with, and the porosity of the formation is further enhanced by fracturing. Thus, Mikus does not disclose a process chamber enclosed by a solid wall, which is now a limitation in claims 1 and 18, and the claims that depend there from. Moreover, Mikus does not disclose a process chamber having "an inlet for a process stream and an outlet for process effluent". Assuming arguendo, the pores in an underground formation could reasonably be construed to be "process chambers", these "process chambers" do not have inlets through which a process steam flows. The oil and water trapped in the formation rock are already present in the pores and occur that way in nature. They do not flow into the pores through inlets.

Claims 5 and 20 are not anticipated by Mikus for the additional reason that Mikus does not disclose a process heater with an oxidation chamber capable of providing heat to a process chamber at a rate of flux sufficient to complete the thermal cracking of hydrocarbons to produce olefins. Further, Mikus does not disclose the reaction conditions recited in the claims 5 and 20 as amended.

As discussed above, the primary purpose of the heat injection process in Mikus is to enhance oil recovery by heating the entrapped oil to increase its mobility and to create fractures in the formation through which the hydrocarbons can migrate and be recovered (col. 1, lines 1-35). Mikus does disclose that in col.1, lines 36-42, that when a formation contains high molecular weight oil or hydrocarbon solids, thermal conduction could also result in pyrolysis of the hydrocarbons in-situ, thereby producing products with lower molecular weights which will therefore be more valuable than the original oil. However, there is no disclosure in Mikus of any specific endothermic chemical reactions, there is no disclosure of the extent to which the reactions are completed and there is no disclosure that olefins are produced. In fact there is no disclosure of any specific products, other than they are lower molecular weight than the high molecular weight oil or hydrocarbon solids originally trapped in the formation.

As would be known to one skilled in the chemical processing arts, the in-situ pyrolysis, which may take place to a limited extent in Mikus, is quite different than the thermal cracking of hydrocarbons to produce olefins, which is one of the endothermic chemical reactions which can be effectively conducted using the present apparatus. As stated on page 14 of the present specification, lines 12-14, the thermal cracking of hydrocarbons to produce olefins takes place at reaction temperatures of 775°C to 950°C and residence times of 0.1 to 0.8 seconds. In contrast to these relatively high reaction temperatures and extremely short reaction times, the heat injection process disclosed in Mikus (and any incidental in-situ pyrolysis) is part of a long term enhanced oil recovery process in which heat at a relatively low rate of flux (e.g., 375 watts per foot) is injected into a formation over a period of months or even years.

Thus, the reaction conditions and environment of the in situ pyrolysis disclosed in the Mikus are quite different than that required for the production of olefins by thermal cracking. Therefore, claims 5 and 20, which are directed to a flameless distributed combustion heater with an oxidation chamber capable of providing heat to a process chamber at a rate of heat flux sufficient to complete the thermal cracking of hydrocarbons to produce olefins, are not anticipated by Mikus. In addition to this distinguishing limitation, the aforementioned reaction temperatures and residence times for the production of olefins are now also included in claims 5 and 20.

Claims 17 and 24 are not anticipated by Mikus for the additional reason that Mikus does not disclose preheating the oxidant by heat exchange with effluent from the process chamber. In paragraph 14 of the current Office action, the Examiner makes the argument that Mikus does anticipate claims 17 and 24 because the embodiment in Fig. 2 of Mikus "clearly shows that the oxidant in Oxidant Conduit is preheated by heat exchange (heat being inherently transferred by

the Heat Conductor 7 and Steel Oxidant Conduit) with reaction products produced in at least one process chamber, traveling upwards." The quoted statement reflects a possible misunderstanding of the Mikus heat injection process, which has resulted in an erroneous anticipation rejection.

Contrary to the statement made on page 27 of the current Office action, the oxidant in Mikus (combustion air) is not preheated by heat exchange with "reaction products produced in at least one process chamber". The heat injector shown in Fig. 2 of Mikus produces heat when preheated air traveling down combustion air conduit 10 is mixed with fuel gas passing through orifices 13 in fuel gas conduit 12 at a temperature above the autoignition temperature of the mixture. The heat generated by the resulting combustion is transferred outward to the formation through cement 7 which is said to be suitable for withstanding elevated temperatures and transferring heat (col. 4, lines 53-56). There is no transfer of heat from the formation inward through cement 7 to the air or fuel conduits.

The transfer to heat outward to the formation causes thermal expansion of the oil and water trapped in the formation rock causing small fractures which permit the hydrocarbons to migrate to one or more recovery wells whereupon they are pumped to the surface. These migrating hydrocarbons would not necessarily travel upwards as shown in the drawing on page 27 of the Office action, but would migrate in various directions through the numerous small fractures in the formation rock to the area of the recovery well(s). There is no disclosure in Mikus of using these migrating hydrocarbons to preheat the oxidant, nor would this happen inherently, since the heat flow is outward from the heat injector through heat transferring cement 7 to the formation.

It is noted that Mikus does disclose that as the combustion products rise in the well bore above the formation being heated, they exchange heat with the combustion air (oxidant) and fuel gas traveling down the flow conduits (col. 6, lines12-15). However, the "combustion products" are effluent from the combustion portion of the heat injector, i.e., the oxidation chamber. They are not effluent from a process chamber. Hence, this disclosure in Mikus does not anticipate claims 17 or 24.

Since Applicant is relying on structural limitations to distinguish the present apparatus over Mikus (e.g., a process chamber enclosed by a solid wall having an inlet for a process stream, and that the apparatus be configured so that the oxidant is preheated by heat exchange with effluent from the process chamber), and not on statements made in the preamble, nor the manner in which the apparatus is intended to be used, nor the contents thereof, the rationale of *In re Otto*, 312 F.2d 937, 938, 136 USPQ 458, 459 (CCPA 1963), etc., *Ex parte Masham*, 2

USPQ2d, 1647 (Bd. Pat. App. & Inter. 1987) and *Ex Parte Thibault*, 164 USPQ 666, 667 (Bd. App. 1969) does not apply.

In summary, claims 1 and 18, as amended, and the claims that depend there from, are clearly distinguishable from Mikus in that the rock in the underground formation in Mikus is porous and is further fractured by the heat injection process. Thus, even if the formation in Mikus could be construed to be a "process chamber", the "process chamber" would not be enclosed by a solid wall. Moreover, the "process chamber" in Mikus would not have an inlet for a process stream, since the oil and water trapped in the formation rock are already present in the pores and occur that way in nature.

Claims 5 and 20 as amended are distinguishable from Mikus for the additional reason that the heat injector in Mikus does not have an oxidation chamber capable of providing heat to a process chamber at a rate of flux sufficient to complete the thermal cracking of hydrocarbons to produce olefins. Moreover, Mikus does not disclose the reaction temperatures and residence times recited in the amended claims.

Claims 17 and 24 are patentable for the additional reason that Mikus does to disclose preheating the oxidant by heat exchange with effluent from a process chamber.

Accordingly, the rejection of claims 1-5, 16-18, 20-21 and 24 anticipated by Mikus should be withdrawn, which action is respectfully requested.

Claim Rejections – 35 U.S.C §103

The rejection of claims 1-7, 14-18 and 20-24 under 35 U.S.C. § 103(a) as being unpatentable over Ruhl (EP 0 450 872) is respectfully traversed.

On page 13 of the current Office Action the Examiner takes the position to the extent that Ruhl, in Fig. 4, does not show a plurality of nozzles distributed along substantially the entire length of the oxidation chamber, it would be obvious to an ordinary artesian at the time of the invention to extend the plurality of nozzles, because Ruhl teaches that said nozzles are "at spaced intervals along its length" (P5/L51-52). The quoted sentence on page 5 lines 51-52 in its entirety reads as follows: "As shown in Figure 4, combustion tube 30 has a feed gas tube 60 which has perforations or holes 64 at spaced intervals along its length and has one end 66 plugged or otherwise closed." Thus, the phrase "at spaced intervals along its length" quoted in the Office action is part of the description of Fig. 4. In other words, Fig.4 shows what is meant by the phrase "perforations or holes 64 at spaced intervals along its length". According to Fig. 4 it means placing the perforations or holes in burner 68 in the middle of combustion tube 30.

Thus, the quoted phrase would not make it obvious to extend the plurality of nozzles along the entire length of the oxidation chamber (combustion tube 30).

While Ruhl does not expressly exclude embodiments where the nozzles are extended to cover substantially the entire length of the oxidation chamber, this is not the issue. The issue is whether the extension of the nozzles over the entire length of the oxidation chamber would be obvious. Applicant contends that based on Ruhl's teachings as a whole, such extension of the nozzles would not be obvious. For example, on page 3, lines 54-55, Ruhl teaches an important feature of the disclosed apparatus is that it allows for the use of relatively low temperature seals (seals 32) to seal the ends of combustion tube 30. Further, on page 5, lines 55-56, Ruhl discloses that plug 66 at the upper end of combustion tube 30 need not resist very hot temperatures. Since Ruhl clearly desires lower temperatures at the ends of combustion tube 30 (where combustion tube 30 is sealed to the plates 16 and 18), it would not be obvious to extend the nozzles along the entire length of the oxidation chamber since such extension would increase the temperatures at the ends of the combustion tube thereby not permitting the use of low temperature seals. Thus, Ruhl in fact teaches away from the extension of the fuel nozzles to cover substantially the entire length of the oxidation chamber (i.e., combustion tube 30).

The subject matter of claims 17 and 24 is not obvious over Ruhl for the additional reason that here is no teaching or suggestion in Fig. 4 of Ruhl of using process effluent (the stream which exits the reactor via outlet 24) to preheat the oxidant (air), which enters the reactor through air inlet 40. While Ruhl discloses it may be desirable to preheat the air fed into the heat generating means, the method contemplated by Ruhl for preheating air is a conventional preheater. Ruhl teaches that "such devices are known in the art and are commercially available" (Page 5, line 45).

As discussed above, the argument made in paragraph 11 of the current Office action is untenable because the inherent heat exchange pointed out by the Examiner takes place between the reaction products in the process chamber and the oxidant in oxidant manifold 42. The effluent from the process chamber in Ruhl is the gas which emerges from outlet 24. Ruhl does not disclose utilizing this effluent stream for preheating the oxidant. Whatever minimal inherent preheating of the oxidant occurs in Ruhl, takes place in the reactor by heat exchange through steel plate 16 with reaction products present in the process chamber. There is no disclosure using effluent from the process chamber for preheating the oxidant. Therefore, claims 17 and 24 are believed to be patentable over Ruhl for this reason as well as the that discussed above in connection with claims 1 and 18, i.e., it would not be obvious to extend the fuel nozzles

64 along the entire length of combustion tube 30 since Ruhl clearly desires lower temperatures at the ends of combustion tube 30.

The rejection of claims 6-7, 14-15 and 22-23 under 35 U.S.C. § 103(a) as being unpatentable over Mikus (USP 5,255,742) as applied to claims 1 and 18 above, is respectfully traversed.

Regarding claims 6-7, 14-15 and 22-23, contrary to the statement on page 13 of the current Office action, Mikus does not disclose all the claim limitations of claims 1 and 18. As discussed above, the porous formation which is further fractured by the heat injection process of Mikus, cannot reasonably be said to be a "process chamber" suitable for completing the type of endothermic chemical reactions recited in claims 6-7, 14-15 and 22-23.

In addition, in order expedite allowance of the claims, Applicant has amended claims 1 and 18 to include the limitation that the process chamber be enclosed by a solid wall and have an inlet for a process stream. Neither of these limitations is taught or suggested by Mikus, the purpose of which is to fracture porous rock formations containing hydrocarbons trapped in the formation. Mikus clearly teaches porous formations and fractured walls. Not solid walls. Moreover, Mikus does not require an inlet for a process stream. The hydrocarbons in Mikus are already present in the porous, rocky underground formation. There is no incoming process stream.

The statement on page 13 of the current Office action that "Additionally Mikus discloses that the heater is used for an endothermic process" apparently is based on the disclosure in col. 1, lines 36-42 of Mikus that: "When the formation contains high molecular weight oil or hydrocarbon solids, thermal conduction could also result in pyrolysis of the hydrocarbons in-situ. The products of the pyrolysis will be of lower molecular weights and will therefore be more valuable than the original oil." (emphasis added).There is no disclosure in Mikus of any specific endothermic chemical reactions, or the extent to which the reactions are completed, or what products are produced, other than they are lower molecular weight than the hydrocarbon solids originally trapped in the formation. Considering the teachings of Mikus as a whole, it is clear that any such in-situ pyrolysis, if it occurs at all, is incidental to the primary purpose of the heat injection process of Mikus, which is to fracture the formation by thermal expansion of the oil and water trapped within the pores, to allow the hydrocarbons to migrate through the fractures in the formation to a point they can be recovered.

More importantly, the teaching that the heater in Mikus may produce some incidental in-situ pyrolysis when heating underground formations, would not render it obvious to use such a

heater to complete the quite different endothermic chemical reactions such as steam methane reforming, the production of styrene by the dehydrogenation of ethyl benzene, etc., recited in claims 6-7, 14-15 and 22-23. While the 375 watts/foot heat flux taught by Mikus may be sufficient to fracture the formation to allow migration and recovery of entrapped hydrocarbons, and may result in some in-situ pyrolysis of solid hydrocarbons to lower weight molecular products, this would not render it obvious to use the heater in Mikus to provide heat to an endothermic chemical reaction involving flowing process streams conducted in an above ground reactor. As stated in the affidavit by Dr. Thomas Mikus these types of reactions involve an order of magnitude greater heat flux than the 375 watts/foot rate produced by the heater in the Mikus reference.

One skilled in the chemical process arts would be aware of the significantly greater heat flux required to complete the type endothermic chemical reactions recited in claims 6-7, 14-15 and 22-23 than the 375 watts per foot produced by the heater in Mikus. For this reason, an ordinary artesian at the time the invention was made would not have "replaced the heaters in various endothermal process chambers with the process heater in Mikus", as stated on page 14 of the current Office Action.

Moreover, such replacement would not "amount to nothing more than to use a known process heater for its intended use in a known environment to accomplish entirely expected result" as also stated on page 14 of the current Office action. The "intended use" of the heater in Mikus is to provide heat to an underground, porous, rocky formation containing trapped hydrocarbons. Not to provide heat to flowing chemical process streams in an above ground reactor. The "environment" in Mikus is an underground formation comprising rocky materials which retain heat and are good insulators and therefore can be heated using a relatively low rate of heat flux. In contrast, the "environment" in which endothermic chemical reactions are conducted involve flowing process streams, which rapidly carry heat away from the heat source and thus require a much higher rate of heat flux. Because of this, such replacement would not accomplish an "entirely expected result". As stated by Dr. Mikus in his affidavit, the results obtained with the flameless, distributed combustion heater of the present invention were in fact surprising and quite unexpected.

For all the foregoing reasons, claims 6-7, 14-15 and 22-23 are believed to be patentable over Mikus. Accordingly, it is respectfully requested this rejection be withdrawn.

The rejection of claims 1-7, 14-18 and 20-24 under 35 U.S.C. § 103(a) as being unpatentable over Ruhl (EP 0 450 872) in view of Mikus (USO 5,255,742) is respectfully traversed.

As discussed above, Ruhl does not disclose a critical feature of the present apparatus recited in each of the present claims that the plurality of fuel nozzles in the fuel conduit be distributed along substantially the entire length of the oxidation chamber. The apparatus in Fig. 1 of Ruhl does not even have a plurality of fuel nozzles and clearly shows a flame in flame zone 50. The apparatus shown in Fig. 4 of Ruhl has a plurality of nozzles (64). However, they are not "distributed along substantially the entire length of said oxidation chamber" (combustion tube 30). Instead, all of perforations or holes 64 in Fig. 4 of Ruhl are spaced in burner zone 68 which represents only a minor portion (appears to be roughly 20%) of the overall length of combustion tube (oxidation chamber) 30. There are no perforations in the upper portion or the lower portion of combustion tube 30. This uneven distribution of fuel nozzles in the oxidation chamber will result in an uneven temperature distribution in combustion tube 30, with the temperature in "burner zone" 68 of the combustion tube 30 being much greater than the temperature in the upper or lower portions of combustion tube 30, which allows the use of low temperature seals to seal the combustion tube to plates 16 and 18.

In an attempt to overcome fact the heaters in Figs. 1 & 4 of Ruhl by design have an uneven temperature distribution (i.e., higher temperatures in the middle of the combustion tube and lower temperature at the ends to permit the use of low temperature seals), on page 16 of the current Office action it is stated that: "Further Ruhl discloses an embodiment wherein the process heater is designed to operate with low temperature differentials (P6/L7-10)". The portion of Ruhl cited by the Examiner in its entirety reads as follows:

"In general, for the apparatus of the present invention, the combustion tubes require a length to inside diameter of typically 500 to 700 in order to achieve the required heat transfer per unit flow volume for a natural gas plus steam reforming application. Even higher ratios are needed, if the reactor is to operate with low temperature differentials."

While the quoted portion of Ruhl teaches how to operate the reactor with lower temperature differentials, this disclosure does not teach or suggest how to achieve a uniform or even temperature profile in combustion tube(s) 30 There is nothing in this teaching that changes the fact that Ruhl desires lower temperatures at the ends of the combustion tubes to allow for the use of low temperature seals. While using tubes with higher tube length to inside diameter ratios results in lower temperature differentials across the reactor, the use of such higher tube length to inside diameter ratios would not create a uniform temperature profile along

the length of combustion tube(s) 30, as long as the nozzles remain located in burner zone 68 in the middle of the combustion tube(s) 30.

In a further attempt to increase the relevancy of Ruhl, it is stated on page 16 of the current Office action that: "To enable operation with low temperature differentials the reference discloses embodiments where the so called 'low temperature seals' are replaced by 'high temperature seals' (P6/L29-31) or where an alternative mode of operation is provided which allows said 'low temperature seals' to effectively operate at high temperatures (P6/L57-P7/L2)". These statements are not accurate for a number of reasons as discussed below.

The first cited portion of Ruhl reads: "Another variation would arrange cocurrent flow of combustion gases and process gases. This scheme would require a hot seal on the exhaust end of the ceramic tubes." Ruhl goes on to state "The cold-end seal could be an O-ring or graphite foil type to allow tube thermal expansion." (Page 6, lines 31-32).

From these statements it can be seen that the replacement of the low temperature seals with high temperature seals has nothing to do with enabling "operation with low temperature differentials". The purpose of the replacement is to arrange for the cocurrent flow of combustion gases and process gas. From these statements taken together, it is clear that in the disclosed variation, only the seals on the exhaust end of the combustion tubes are replaced with high temperature seals. The seals on the opposite "cold-end" of the combustion tubes in the vicinity of the feed inlet and air and fuel inlets would continue to be low temperature seals. Thus, this variation in which the combustion gases and process gas are in cocurrent flow would not have a uniform or even temperature profile. The temperature at the in the burner zone and the exhaust end of the combustion tubes would be higher than the temperatures in the "cold-end" of the combustion tubes .

The second cited portion of Ruhl reads "The upper operating temperature of the graphite foil seals is limited by oxidation by the air present on one side. If a controlled very slow leakage of process gas is permitted to occur through the seal, this could sweep this air away from the seal material and permit the seals to exhibit long life at higher temperatures. Such an arrangement may be termed a purged seal condition."

Ruhl does not define what is meant by "higher temperatures". All we know is that use of a "purged seal condition" permits the use of the relatively low temperature seals at somewhat higher temperatures than if the seals were exposed to an oxidizing atmosphere. Ruhl does not teach (nor would it be reasonable to expect) that use of a purge seal condition would allow the relatively low temperature graphite foil seals to be used in place of high temperature seals, such as fused glass or ceramic cement seals. Nor does Ruhl teach that if a "purged seal condition" is

used, the fuel nozzles in Fig. 4 should be placed in a location other than burner zone 68, or that a different plug 66 should be used, other than a plug that need not resist very high temperatures. Thus, when the disclosures of Ruhl are taken as a whole, the teaching that the preferred relatively low temperature graphite foil seals can be operated under a purged seal condition at some undefined "higher temperature" would not render it obvious to distribute the fuel nozzles along substantially the entire length of the oxidation chamber.

Turning now to Mikus, Applicant continues to maintain that the underground formation (which comprises porous rocks containing trapped hydrocarbons and water), and which is further fractured by the heat injection process of Mikus, cannot reasonably be said to be a "process chamber" suitable for completing the type of endothermic chemical reactions of the type recited in claims 6-7, 14-15 and 22-23. However, in order to expedite allowance of the application, claims 1 and 18 have been amended to require the process chamber be enclosed by a solid wall and that the process chamber have an inlet for a process stream. Neither of these limitations is taught or suggested by heat injection process of Mikus, the primary purpose of which is to fracture porous rock formations to release the trapped hydrocarbons so they can be recovered. Mikus clearly teaches porous formations and fractured walls. Not solid walls. Moreover, Mikus does not require an inlet for a process stream. The hydrocarbons in Mikus are already present in the porous, rocky underground formation. There is no incoming process stream.

Examiner's Basis for Combining Ruhl with Mikus

Despite the fact that the heaters in Figs. 1 and 4 in Ruhl, by design, have an uneven or non-uniform temperature distribution in order to allow the use of low temperature seals, on page 18 of the subject Office action the Examiner takes the position that:

> "It would have been obvious to one of ordinary skill in the art at the time the invention was made to replace the heater in the apparatus of Ruhl with the heater of Mikus for the purpose of providing more even temperature distribution throughout the length of the burner and lowering the costs of said apparatus."

Applicant's Arguments as to Why Ruhl is Not Properly Combinable with Mikus

It basic patent law that the mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination. *In re Mills*, 916 F.2d 680, 16 USPQ 2d 1430 (Fed. Cir. 1990). Although a prior

art device "may be capable of being modified to run the way the apparatus is claimed, there must be a suggestion or motivation in the reference to do so." 916 F.2d at 682, 16 USPQ2d at 1432.

Applicant submits that in the present case, there is no suggestion or motivation in the Ruhl or Mikus references for modifying them in the manner the Examiner has done. The Examiner's position that it would be obvious "to replace the heater in the apparatus of Ruhl with the heater of Mikus for the purpose of providing more even temperature distribution throughout the length of the burner and lowering the costs of said burner" is based on the erroneous assumption that an "even" or "uniform" temperature distribution throughout the length of the burner, which is taught by Mikus to be beneficial in heating subterranean formations, is also beneficial in heater used by Ruhl to provide heat to his endothermic reaction apparatus. This assumption is not correct, and in fact contrary to the disclosure in Ruhl.

As previously discussed, the heater (combustion tube 30) in the apparatus in Fig. 1 of Ruhl does not have a "even" or "uniform" temperature distribution along the length of the combustion tube, nor is there any teaching that an "even" or "uniform" temperature distribution is desired. To the contrary, Ruhl prefers the use of low temperature seals 32 to hold the combustion tube in place. Therefore, the combustion tube in Fig. 1 of Ruhl intentionally has the highest temperatures in flame zone 50 (in the middle of combustion tube 30), with lower temperatures at the upper and lower portions of the combustion tube to allow the use of low temperature seals to join the combustion tube to the tube sheets (plates 16 and 18).

Likewise the heater in Fig. 4 of Ruhl does not have an "even" or "uniform" temperature distribution since all of the fuel nozzles in Fig. 4 are in the "burner zone" 68 in the middle portion of combustion tube 30. There are no fuel nozzles in the upper portion or lower portion of the combustion tube 30. Consequently, these portions will have lower temperatures than the temperature in the "burner zone" 68, thereby allowing the use of low temperature seals. Lower temperatures in the upper portion of combustion tube also allow the use of a plug 66 at the upper end of the fuel tube "which need not resist very hot temperatures".

Since the heaters in both Fig. 1 and Fig. 4 of Ruhl by design have a non-uniform temperature distribution along their length, and since there's no indication in Ruhl that an "even" or "uniform" temperature distribution is desirable, it would not be obvious to one skilled in the art to replace the heater in the apparatus of Ruhl with the heater in Mikus for "the purpose of providing more even temperature distribution throughout the length of the burner", as contended by the Examiner. The teaching or suggestion to combine these references and a reasonable expectation for success must both be found in the prior art, and not based on applicant's

disclosure. *In re Vaeck*, 947 F.2d 488, 20USPQ2d 1438 (Fed. Cir. 1991). Applicant submits that in the present case the prior art does not suggest replacing the heater in either Fig. 1 or Fig. 4 of Ruhl with the heat injector in Mikus, nor does the prior art create a reasonable expectation that such substitution would be successful.

The fact that the heaters used in Figs. 1 and 4 of Ruhl have a non-uniform temperature distribution along their length, while the heater in Mikus is designed to produce an "even" or "uniform" temperature distribution, again illustrates the differences between the problems to which Ruhl and Mikus were directed, and why these references are not properly combinable. Ruhl wanted to design a compact reactor apparatus which can employ a large number and high density of burner tubes which could operate at high temperatures and pressures to achieve a high conversion of hydrocarbon with high efficiency. (Page 3, lines 50-53). Yet Ruhl also wanted an apparatus which allows for the use of relatively low temperature seals to connect the burner tubes to the tube sheets. (Page 3, lines 54-55). Therefore, Ruhl designed combustion tube 30 to have lower temperatures in the general vicinity of the seals with higher temperatures in the middle of the heater (i.e., in "flame zone" 50 in the case of Fig.1, and in "burner zone" 68 in the case of Fig. 4).

Mikus, on the other hand, was concerned with recovery of hydrocarbons entrapped in pores in an underground formation and found that the provision of uniform heat to the formation at a relatively low heat flux was beneficial. Mikus was not concerned with designing compact reaction apparatuses, or conducting the type of endothermic chemical reactions of interest to Ruhl which require a high rate of heat flux, or joining combustion tubes to tube sheets with low temperature seals. Since the problems to which Ruhl and Mikus are directed, and the solutions they found, are quite different, it clearly would not be obvious to replace the heater in Ruhl with the heater of Mikus " for the purpose of providing more even temperature distribution throughout the length of the burner". Such substitution would not solve the problems to which Ruhl was directed, nor achieve the benefits Ruhl desired.

Applicant further submits that it would not be obvious to replace the heater in the apparatus of Ruhl with the heater of Mikus for the purpose of "lowering the costs of said apparatus". The heater in Fig. 1 utilizes combustion with flames, which will generate a high temperature in the flame zone, and lower temperatures in the upper and lower portions of the combustion tube which permits the use of low temperature seals to join the combustion tubes to the tube sheets. It is doubtful that substituting the flameless heater of Mikus (which has relatively low rate of heat flux) for the flame-type heater used in the apparatus of Fig.1 of Ruhl would provide sufficient heat flux to complete the desired endothermic chemical reactions. If it

did, it is likely that the temperatures in the upper and lower portions of the combustion tubes would be too high to use the low temperature seals favored by Ruhl. Thus, it is unlikely that the substitution of heaters suggested by the Examiner would even work, and in any case would involve a significant redesign of the reactor apparatus in Fig. 1 of Ruhl, and may necessitate the use of high temperature seals, which could actually increase the cost of the apparatus.

Applicant submits that when the Ruhl and Mikus references are considered as a whole, rather that suggesting to one skilled in the art to replace the heater of Ruhl with the heat injector of Mikus, they provide at least two significant reasons for not replacing the heater of Ruhl with the heat injector of Mikus. (1) The heaters used to provide heat to the endothermic reaction apparatuses in Figs. 1 and 4 of Ruhl have a non-uniform temperature distribution by design, and there is no indication that an even temperature distribution is desired, and (2) endothermic chemical reactions, such as the reforming of light hydrocarbons, which are of interest to Ruhl, require far greater heat flux than the approximately 375 watts per foot produced by the heater injectors used by Mikus to heat subterranean formations, as stated in the affidavit by Dr. Thomas Mikus.

It is noted that Ruhl does teach on page 5, lines 38-39 that "as many as many thousands of combustion tubes could be incorporated in an appropriate size reformer apparatus". However, this disclosure refers to the small diameter, ceramic combustion tubes preferred by Ruhl, which have higher temperatures in the flame zone or burner zone in the middle portion of the combustion tube and lower temperatures at the ends to allow the use of relatively low temperature seals. Thus, the fact Ruhl teaches many combustion tubes having small diameter and an uneven temperature distribution can be used in a reformer apparatus, does not provide a motivation to replace these combustion tubes with the quite different type and size combustion tube disclosed in Mikus, which not only have larger diameter, but which also produce an even temperature distribution, which is contrary to the combustion tube design in Ruhl.

In addition to the structural limitations recited in claims 1 and 18, Applicant is relying on the limitation in claims 17 and 24 that the oxidant be preheated by heat exchange with effluent from the process chamber to distinguish these claims from the cited art. Applicant considers the additional limitation recited in claims 17 and 24 to be a structural limitation, since it pertains to a particular configuration of the process heater of the invention in which the oxidant is preheated by heat exchange with gaseous effluent from the process chamber. Neither Ruhl nor Mikus teach or suggest such this embodiment of Applicants process heater. Ruhl appears to contemplate use of a separate, external preheater to preheat the oxidant, and states such preheaters are known in the art and are commercially available (Ruhl, page 5, lines 44-45).

Some minimal preheating may occur in Ruhl by heat exchange between the reaction products in the process chamber and the air in manifold 42. However, there is no disclosure of using the effluent from the process chamber (i.e., the stream exiting the reactor through outlet 24 to preheat the oxidant.

Mikus discloses preheating the oxidant, at least in part, by heat exchange between the combustion products rising in the well bore and combustion air and the fuel gas traveling down the flow conduits (Mikus, Col. 6, lines 12-15). There is no suggestion in Mikus of using "effluent" from a process chamber (which according to the Examiner's interpretation would be the hydrocarbons released from the fractured, porous underground formation) to preheat the oxidant. As discussed above, in the heat injection process disclosed in Mikus, the heat flows from the heat injector outward through cement 7 into the formation. There is no flow of heat from the formation inward through the cement to the air conduit or fuel conduit which comprises the heat injector. Thus, Mikus does not teach or suggest preheating the oxidant with effluent from a process chamber.

Since Applicant is relying on structural limitations to distinguish the present apparatus over Mikus (e.g., that the plurality of fuel nozzles be distributed along substantially the entire length of the oxidation chamber, that the flameless distributed combustion heat process heater have a process chamber enclosed by a solid wall having an inlet for a process stream, and that the oxidant be preheated by heat exchange with effluent from the process chamber), and not on statements made in the preamble, nor the manner in which the apparatus is intended to be used, nor the contents thereof, the rationale of *In re Otto*, 312 F.2d 937, 938, 136 USPQ 458, 459 (CCPA 1963), etc., *Ex parte Masham*, 2 USPQ2d, 1647 (Bd. Pat. App. & Inter. 1987) and *Ex Parte Thibault*, 164 USPQ 666, 667 (Bd. App. 1969) does not apply.

For the foregoing reasons, claims 1-7, 14-18 and 20-24 are believed to be patentable over Ruhl in view of Mikus. Accordingly, it is respectfully requested that the rejection of these claims under 35 U.S.C. § 103(a) be withdrawn.

Response to Points Raised by Examiner in Response to Applicant's Arguments

In this section Applicant will address the points raised in Paragraphs 9-17 of the current Office Action, which were made by the Examiner in response to Applicant's previous arguments. Some of the points raised by the Examiner in Paragraphs 9-17 may have already been addressed to some extent in the Remarks/Argument section above. Applicant apologizes for any duplication, but wants to ensure that all of the Examiner's questions/concerns are answered in the hope that the application which has been pending for over six years and has been on

appeal twice only to have the prosecution reopened, may finally be allowed and passed to issue.

Paragraph 9. Applicant agrees that claim terms should be given there broadest reasonable interpretation. However, it is not reasonable to interpret the term "oxidation chamber" to include only that part of combustion tube 30 surrounding the burner zone 68. Combustion tube 30 in the apparatus of Fig.4 of Ruhl runs the full length of the reactor. There are no walls or barriers dividing combustion tube 30 into separate sections or compartments. Oxidant and fuel are free to mix and combust anywhere in combustion tube 30. Hence, it is unreasonable to define the oxidation chamber in Ruhl as being only that small portion of combustion tube 30 surrounding perforations 64. Clearly the entire combustion tube 30 is the oxidation chamber in the reaction apparatus in Fig.4 of Ruhl. Since the fuel nozzles (perforations 64) in Ruhl are distributed over only a small portion (about 20%) of combustion tube 30 (i.e., in burner zone 68), Ruhl does not met the limitation in each of the present claims that the fuel nozzles be distributed along substantially the entire length of the oxidation chamber.

The Examiner points out that while Fig. 4 of Ruhl may not explicitly show nozzles along the entire length of feed tube 60, the disclosure of Ruhl is not limited to the embodiment shown in Fig. 4. The Examiner notes that Ruhl on page 5, lines 51-53 teaches that the nozzles are spaced at intervals along the length of feed tube 60, Further the reference is silent as to any requirements of a "non-burner zone"- area of the feed tube 60 which is free of nozzles. In view of this disclosure, the Examiner argues it would be obvious to one skilled in the art "to extend said plurality of nozzles to cover substantially the entire length of the oxidation chamber.

The quoted disclosure on page 5, lines 51-52, of Ruhl in its entirety reads as follows: "As shown in Figure 4, combustion tube 30 has a feed gas tube 60 which has perforations or holes 64 at spaced intervals along its length and has one end 66 plugged or otherwise closed." Thus, the phrase "at spaced intervals along its length" cited in the Office action is part of the description of Fig. 4. In other words, Fig.4 shows what is meant by the phrase "perforations or holes 64 at spaced intervals along its length". According to Fig. 4 it means placing the perforations or holes in the middle of combustion tube 30, i.e., in burner zone 68. Thus, the quoted phrase would not make it obvious to extend the plurality of nozzles along the entire length of the oxidation chamber (combustion tube 30).

While Ruhl may be "silent as to any requirements of a 'non-burner zone' – area of the feed tube 60 which is free of nozzles", this is not the issue. The issue is not whether Ruhl expressly excludes the extension of the plurality of nozzles to cover substantially the entire

length of the oxidation chamber. The issue is whether such extension would be obvious. Applicant contends that such extension would not be obvious in view of Ruhl's teachings on page 3, lines 54-55 and page 5, lines 55-56, that the apparatus of the invention allows for the use relatively low temperature seals to seal the ends of combustion tube 30 to plates 16 and18, and a that plug 66 (located at the upper end of combustion tube 30) need not resist very hot temperatures. Since Ruhl clearly desires lower temperatures at the ends of combustion tube 30 to allow the use of relatively low temperature seals and a plug that need not resist very hot temperatures, it would not be obvious to extend the nozzles 64 along the entire length of combustion tube 30.

The Examiner finds Applicant's arguments with respect to low temperature seals limiting the area of the oxidation chamber in Ruhl in which flameless combustion would occur to be unpersuasive "because Ruhl teaches an alternative to said low temperature seals. On page 6, lines 29-32 Ruhl teaches 'hot seals' which can comprise, for example, fused glass or ceramic cement."

The quoted disclosure on page 6, lines 29-32, of Ruhl in its entirety reads as follows:

> "Another variation would arrange cocurrent flow of combustion gases and process gases. This scheme would require a hot seal on the exhaust end of the ceramic tubes. Such a seal might be made of fused glass or a ceramic cement, for example. The cold end seal could be an O-ring or graphite foil type to allow tube thermal expansion."

The quoted disclosure would not make it obvious to extend the plurality of nozzles along the entire length of the oxidation chamber (combustion tube 30), since only the exhaust ends of the combustion tube would have a hot seal, and thus could withstand higher temperatures. The other end of the combustion tubes would continue to have a "cold-end seal" such as an O-ring or graphite foil seal, which could not withstand higher temperatures. Therefore, in this alternative embodiment, the combustion tube(s) would still have a non-uniform temperature profile. Since Ruhl teaches that an important "feature of present design is that it allows for the use of lower temperature seals where the combustion tubes are joined to the tube sheet" (page 4, lines 48-49), there is no incentive to replace the low temperature seals on both ends of the combustion tube with "hot seals".

The Examiner also finds Applicant's arguments with respect to low temperature seals limiting the area of the oxidation chamber in Ruhl in which flameless combustion would occur to be unpersuasive because Ruhl teaches "that while the upper operating temperature of graphite

seals is limited by oxidation, the apparatus can be operated with a controlled very slow leakage of process gas through the seal to sweep the air away from the seal material and permit seals to exhibit long life at higher temperatures (see Ruhl, P6/L57-P7/L2)".

The cited portion of Ruhl in its entirety reads "The upper operating temperature of the graphite foil seals is limited by oxidation by the air present on one side. If a controlled very slow leakage of process gas is permitted to occur through the seal, this could sweep this air away from the seal material and permit the seals to exhibit long life at higher temperatures. Such an arrangement may be termed a purged seal condition."

Ruhl does not define what is meant by "higher temperatures". All we know is that use of a "purged seal condition" permits the use of the relatively low temperature seals at somewhat higher temperatures than if the seals were exposed to an oxidizing atmosphere. Ruhl does not teach (nor would it be reasonable to expect) that use of a purge seal condition would allow the relatively low temperature graphite foil seals to be used in place of high temperature seals, such as fused glass or ceramic cement seals. Nor does Ruhl teach that if a "purged seal condition" is used, the fuel nozzles in Fig. 4 should be placed in a location other than burner zone 68, or that a plug 66, other than a plug that need not resist very high temperatures should be used. Thus, when the disclosures of Ruhl are taken as a whole, the teaching that the preferred relatively low temperature graphite foil seals can be operated under a purged seal condition at some undefined "higher temperature" would not render it obvious to extend the fuel nozzles along substantially the entire length of the oxidation chamber.

Paragraph 10. Applicant is relying on structural limitations to distinguish the present claims over the references and not on the fact the apparatuses in the prior art are not able to achieve the range of temperature profiles that are achieved by Applicant's apparatus. It is because of structural limitations, such as the placement of a plurality of fuel nozzles along substantially the entire length of the oxidation chamber, that Applicant's apparatus is able to tailor the temperature profile in the process chamber to whatever profile is needed to complete the endothermic chemical reaction being conducted therein. Since Applicant is relying on structural limitations rather than specific temperature profiles to distinguish over the references, there is no need to recite particular temperature profiles in the claims. It is noted that particular temperature profiles are claimed in Applicant's co-pending application containing method claims.

Paragraph 11. In response to Applicant's argument that Ruhl does not disclose preheating the oxidant by heat exchange with effluent from the process chamber, the Examiner reproduces a portion of Fig. 4 of Ruhl, which it is said "clearly shows that the oxidant in Oxidant

Inlet Manifold 42 is preheated by heat exchange (heat being inherently transferred by the Steel Plate 16 with reaction products produced in the process chamber and traveling towards the Outlet 24".

Applicant agrees it is possible that there may be some inherent heat transfer from the reaction products in the process chamber to the oxidant in manifold 42. However, claims 17 and 24 call for preheating the oxidant with effluent from the process chamber. "Effluent" is the gaseous stream that exits the process chamber via outlet 24. Ruhl does not disclose using this effluent stream to preheat the oxidant. Instead Ruhl teaches using a known, commercially available preheater device to preheat the oxidant (Ruhl, page 5, lines 44-45). Whatever minimal additional preheating occurs, takes place as the result of heat exchange between the reaction products in the process chamber and the oxidant in manifold 42. Ruhl does not disclose preheating the oxidant using effluent from the process chamber (i.e., the stream exiting the reactor via outlet 24).

Paragraph 12. Applicant acknowledges that Mikus does disclose that the injection of heat into a formation may in some cases result in in-situ pyrolysis of hydrocarbons which is an endothermic chemical reaction. More specifically, Mikus discloses in col. 1, lines 36-42, when a formation contains high molecular weight oil or hydrocarbon solids, thermal conduction could also result in pyrolysis of the hydrocarbons in-situ, thereby producing products with lower molecular weights which will therefore be more valuable than the original oil. However, there is no disclosure in Mikus of any specific endothermic chemical reactions, or the extent to which the reactions are completed, or what products are produced, other than they are lower molecular weight than the hydrocarbon solids originally trapped in the formation.

Considering the teachings of Mikus as a whole, it is clear that any such in-situ pyrolysis, if it occurs at all, is incidental to the primary purpose of the heat injection process of Mikus, which is to fracture the formation by thermal expansion of the oil and water trapped within the pores, to allow the hydrocarbons to migrate through the fractures in the formation to a point they can be recovered. However, in order to expedite allowance of the claims, claims 1 and 18 have been amended to provide that the process chamber be "enclosed by a solid wall, having an inlet for a process stream and an outlet for process effluent". These amendments clearly distinguish the instantly claimed process from Mikus in that the formation rock in Mikus is porous to begin with, and the porosity of the formation is further enhanced by fracturing. Thus, Mikus does not teach or suggest a process chamber enclosed by a solid wall, which is now a limitation in claims 1 and 18, and the claims that depend there from. Moreover, Mikus does not disclose a process chamber having "an inlet for a process stream and an outlet for process effluent". Assuming

arguendo, the pores in an underground formation could reasonably be construed as "process chambers", these "process chambers" do not have inlets through which a process steam flows. The oil and water trapped in the formation rock are already present in the pores and occur that way in nature. They do not flow into the pores through inlets.

Paragraph 13. While Mikus teaches that the injection of heat into a formation may in some cases result in in-situ pyrolysis of hydrocarbons which is an endothermic chemical reaction, Mikus does not teach using a heat flux sufficient to complete the specific types of endothermic chemical process recited in claims 5-7, 14-15, 20 and 22-23 and therefore does not anticipate those claims for this reason as well as the reasons discussed elsewhere. While a specific rate of heat flux is not recited in claims 5-7, 14-15, 20 and 22-23, these claims do require that a controllable heat flux be provided to the process chamber at a sufficiently high rate to complete the endothermic chemical process conducted therein. One skilled in the chemical arts would know that the 375 watts/foot rate of heat flux produced by the heat injector in Mikus to heat underground formations, would not be sufficient to complete the specific types of endothermic chemical reactions recited in claims 5-7, 14-15, 20 and 22-23. Therefore, the aforementioned underlined limitation is believed to distinguish these claims over Mikus, without having to recite specific rates of heat flux in the claims. In any case all of the claims are believed distinguishable over Mikus based on the structural limitations discussed above. Also claims 5 and 20 have been amended to recite specific reaction temperatures and residence times.

Paragraph 14. In response to Applicant's argument that Mikus does not disclose preheating the oxidant by heat exchange with effluent from the process chamber, the Examiner reproduces a portion of Fig. 2 of Mikus which it is said " clearly shows that the oxidant in Oxidant Conduit is preheated by heat exchange (heat is being inherently transferred by Heat Conductor 7 and Steel Oxidant Conduit) with reaction products produced in at least one process chamber traveling upwards".

Contrary to this statement, the oxidant in Mikus (combustion air) is not preheated by heat exchange with "reaction products produced in at least one process chamber traveling upwards". The heat injector shown in Fig. 2 of Mikus produces heat when preheated air traveling down combustion air conduit 10 is mixed with fuel gas passing through orifices 13 in fuel gas conduit 12 at a temperature above the autoignition temperature of the mixture. The heat generated by the resulting combustion is transferred outward to the formation through cement 7 which is said to be suitable for withstanding elevated temperatures and transferring heat (col. 4, lines 53-56). There is no transfer of heat from the formation inward through cement 7 to the air or fuel conduits.

The transfer to heat outward to the formation causes thermal expansion of the oil and water trapped in the formation rock causing small fractures which permit the hydrocarbons to migrate to one or more recovery wells whereupon they are pumped to the surface. These migrating hydrocarbons would not necessarily travel upwards as shown in the drawing in Paragraph 14, but would migrate in various directions through the numerous small fractures in the formation rock to the area of the recovery well(s). There is no disclosure in Mikus of using these migrating hydrocarbons (which would be the "effluent" from the fractured porous "process chambers") to preheat the oxidant, nor would this happen inherently, since the heat flow is outward from the heat injector through heat transferring cement 7 to the formation.

Paragraph 15. Applicant believes it is error for the Examiner to disregard the Affidavit of Dr. Thomas Mikus, the inventor on the Mikus reference and a co-inventor on the present application. As an inventor Dr. Mikus is considered one of extraordinary skill in the art. Yet the Examiner ignores the Dr. Mikus' testimony that because of the order of magnitude greater difference in heat flux requirements between endothermic chemical reactions, such as the thermal cracking of hydrocarbons to produce ethylene, and the heat flux required to heat underground formations (i.e., 3,500 to 7,000 watts/foot compared to 375 watts/foot), the applicability of flameless distributed combustion was unforeseen and not predictable. Instead, the Examiner takes the position that one of ordinary skill in the art could manipulate the multitude of variables that affect the heat flux of a burner to compensate for the order of magnitude difference in heat flux requirements. If only some minor increase in the rate of heat flux was required in order to complete the type of endothermic chemical reactions of interest to Ruhl, Applicant might agree that manipulation of the multitude of available variables is within the capability of one of ordinary skill in the art. However, in view of the order of magnitude difference in heat flux required, Applicant submits that adaptation of flameless, distributed combustion to complete the very different type of endothermic chemical reactions to which the present apparatus is directed, requires more than ordinary skill in the art. It represents invention.

Applicant has previously noted the fact that there may be "a multitude of variables" which could be modified or manipulated by one skilled in order to meet the claimed invention is not sufficient by itself to establish *prima facie* obviousness without some objective reason to combine the teachings of the references. *Ex parte Levengood*, 28 USPQ 1300 (Bd. Pat. App. & Inter. 1993). On page 28 of the current Office action the Examiner cites several teachings in the references, which the Examiner contends would make it obvious to replace the heater in Ruhl with the heater in Mikus. They do not for the following reasons.

For example, Ruhl's teaching on page 5, line 38-39, that "as many as many thousands of combustion tubes could be incorporated in an appropriate size reformer apparatus", refers to the relatively small diameter (e.g., 0.4 inch) ceramic combustion tubes which have higher temperatures in the flame zone in the middle portion of the combustion tube and lower temperatures at the ends to allow the use of relatively low temperature seals. (See page 5, lines 39-40, page 6, lines 19-23, and Figs. 1, 2 and 3 of Ruhl. The combustion tube in Fig. 4 of Ruhl also has an uneven temperature distribution.) Thus, the fact Ruhl teaches many relatively small diameter combustion tubes having an uneven temperature distribution can be used in a reformer apparatus, does not provide a motivation to replace these combustion tubes with the relatively large diameter (e.g., 4-8 inch) combustion tubes disclosed in Mikus, which produce an even temperature distribution and a low rate of heat flux. (See Mikus col. 5, lines 23-25 and lines 46-55 and col. 10, lines 8-12).

Likewise, the teaching on page 7, lines 4-7 of Ruhl, that "The maximum temperature of the combustion gases within the combustion tubes may be varied by adjusting the fuel composition and the fuel and air flow rates" refers to varying the maximum temperature of the combustion tubes in Ruhl which have an uneven temperature distribution. This teaching does not tell one skilled in the art how to produce a order of magnitude (i.e., a ten fold increase) in the rate of heat flux in the heater in Mikus, nor does not provide any motivation to replace the heater in Ruhl which has an uneven temperature distribution with the heater in Mikus which has an even temperature distribution.

Finally, the teaching cited by the Examiner in col. 5, lines 15-25, of Mikus that "The heat that can be transferred into the formation increases significantly with increasing casing diameter" and that "A casing of between about 4 and about 8 inches in internal diameter will typically provide the optimum trade-off between initial cost and heat transfer", may suggest a means to optimize the heat transfer to an underground formation, but does not provide motivation to replace the heater in Ruhl.

Ruhl clearly prefers the "use of small-diameter ceramic combustion tubes" to facilitate "a denser packing of burner tubes than has been previously available in prior art apparatus" (Ruhl, page 5, lines 39-40). "The preferred combustion tube inside diameter is usually equal to the tube separation distance (expressed as inside tube to inside tube surface). Thus, if the separation distance were 0.4 inches, the preferred tube ID would be 0.4 inches for a centerline spacing of 0.8 inches" (Ruhl, page 6, lines 19-21).

In view of Ruhl's desire for a compact apparatus which is achieved by employing many densely packed, relatively small diameter (e.g., 0.4 inch) burner tubes, it is submitted one skilled

in the art would not be motivated by Mikus teaching of heat injectors with an optimum diameter of 4 to 8 inches for heating underground formations, to replace the densely packed, small diameter, burner tubes of Ruhl with the relatively large diameter burner tube preferred by Mikus. Such replacement would not result in a compact reactor, would not provide the same heat flux as many densely packed small diameter tubes, and in any case would not provide the uneven temperature distribution needed to allow for the use of low temperature seals and/or plugs. In fact, Mikus' teaching that the heat transferred to the formation can be increased by increasing casing diameter is a reason for not replacing the heater in Ruhl with the heat injector in Mikus, since Ruhl achieves a high heat flux by using many tubes of a small (reduced) diameter so that they can be densely packed.

On page 29 of the current Office action the Examiner "notes that a reasonable expectation for this proposed use of the flameless heater of Mikus in the apparatus of Ruhl is supported by the fact that Ruhl, in Fig. 4, discloses an embodiment wherein burner located in an oxidation zone comprises at least one fuel conduit comprising a plurality of fuel nozzles and does not have a flame." While Fig. 4 of Ruhl does disclose an embodiment having an oxidation zone comprising a fuel conduit with a plurality of nozzles and does not show a flame, as previously discussed, the plurality of nozzles in Fig. 4 of Ruhl are located in burner zone 68 in the middle of combustion tube 30. There are no nozzles at either end of the combustion tube where the combustion tube is sealed to plates 16 and 18 with low temperature seals 32. Because of this uneven temperature distribution in the heater in Fig. 4 of Ruhl, and because of the lower rate of heat flux taught by Mikus, it is not reasonable to expect the flameless heater in Mikus would work as a replacement for the heater in Fig. 1 of Ruhl.

If one skilled in the art wanted to replace the heater in Fig. 1 of Ruhl with a flameless heater, they would have the greatest expectation of success if they choose the flameless heater in Fig. 4 of Ruhl, which has the same uneven temperature profile and uses the same low temperature seals as the heater in Fig. 1 of Ruhl. One skilled in the art would not choose the flameless heater in Mikus for such replacement.

Paragraph 16. Applicant's position is that it would not be obvious to replace the heater either in Fig.1 or Fig. 4 of Ruhl with the heater in Mikus because (1) the heater in Ruhl by design produces uneven temperature profile since the fuel nozzle(s) are located in the middle of the combustion tube 30 (in burner zone 68 or flame zone 50) while the ends of the combustion tube 30 is sealed with relatively low temperature seals and (2) the type of endothermic chemical reactions of interest to Ruhl and Applicant require an order of magnitude greater heat flux than that produced by the heater in Mikus. Ruhl repeatedly mentions the use of low temperature

seals as an important feature of his compact reactor apparatus design (page 3, lines 54-55 and page 4, lines 48-49). It is for this reason, based on the teachings of the reference itself, that Applicant contends it would not be obvious to replace the low temperature seals in Ruhl with hot seals on both ends of the combustion tube(s), in order to be able to extend the fuel nozzles over substantially the entire length of the oxidation chamber (combustion tube 30).

With regard to the teaching on page 6 of Ruhl, lines 29-32, Applicant's description of this teaching is not overly narrow but based on a direct quote of the cited portion of Ruhl. Ruhl on page 6, lines 29-32 states that: "Another variation would arrange cocurrent flow of combustion gases and process gases. This scheme would require a hot seal on the exhaust end of the ceramic tubes. Such a seal might be made of fused glass or a ceramic cement, for example. The cold-end seal could be an O-ring or graphite foil type to allow tube thermal expansion."

From this disclosure it is clear that the reason for using a hot seal on the exhaust end of the ceramic tubes was because such seals were required in the variation where the combustion gases flowed concurrently with and process gases. On the other end of the ceramic tubes were hot seals were not required, Ruhl used the preferred low temperature seals.

Considering the teachings of Ruhl as a whole, rather than suggesting the type of seal used is not critical and that various known seals can be used successfully employed in the reactor, Ruhl suggests that the use of relatively low temperature seals is an important feature of the invention, and that such low temperature seals should be used except in those cases where hot seals are required. The only instance in which a "hot seal" was required in Ruhl was in one variation, and then only in the exhaust end of the combustion tubes. Otherwise, Ruhl used the preferred low temperature seals.

Regarding the "purged seal condition", the cited portion of Ruhl (P6/L57-P7/2) only discloses that use of this condition permits the seals to exhibit long life at "higher temperatures". Ruhl does not define what is meant by "higher temperatures". All we know is that use of a "purged seal condition" permits the use of the relatively low temperature seals at somewhat higher temperatures than if the seals were exposed to an oxidizing atmosphere. Ruhl does not teach (nor would it be reasonable to expect) that use of a purge seal condition would allow the relatively low temperature graphite foil seals to be used in place of high temperature seals, such as fused glass or ceramic cement seals. Nor does Ruhl teach that if a "purged seal condition" is used, the fuel nozzles in Fig. 4 should be placed in a location other than burner zone 68, or that a plug 66, other than a plug that need not resist very high temperatures should be used. Thus, when the disclosures of Ruhl are taken as a whole, the teaching that the preferred relatively low temperature graphite foil seals can be operated under a purged seal condition at some

undefined "higher temperature" would not render it obvious to extend the fuel nozzles along substantially the entire length of the oxidation chamber.

Paragraph 17. In response to Applicant's argument that Ruhl desires an uneven temperature distribution (i.e., higher temperatures in the middle of the combustion tube and lower temperature at the ends to permit the use of low temperature seals), the Examiner points to the disclosure on Page 6, lines 7-10 of Ruhl, which discloses a method of operating the reactor with low temperature differentials. The Examiner contends that in view of this teaching and the teaching in Mikus, which discloses a flameless burner having low temperature differentials, it would have been obvious to substitute the burner in Ruhl with the burner in Mikus. A closer reading of the references reveals that this argument is untenable.

The quoted portion of Ruhl in its entirety reads as follows:

"In general, for the apparatus of the present invention, the combustion tubes require a length to inside diameter of typically 500 to 700 in order to achieve the required heat transfer per unit flow volume for a natural gas plus steam reforming application. Even higher ratios are needed, if the reactor is to operate with low temperature differentials."

From the foregoing, it can be seen that the way Ruhl teaches to redesign the reactor to achieve low temperature differentials is by increasing the length to inside diameter ratio of the combustion tubes, i.e., by using combustion tubes of greater length or smaller diameter. Ruhl does not teach or suggest achieving lower temperature differentials by changing the location of the fuel nozzles which would still be in the middle of the combustion tubes (in flame zone 50 or burner zone 68). Nor does Ruhl suggest achieving the lower temperature differentials by using seals other than the preferred low temperature seals. Thus, the redesigned low temperature differential reactor in Ruhl would have longer combustion tubes or tubes with smaller inside diameter. However, the combustion tubes would still have a non-uniform temperature profile.

The heater in Mikus, on the other hand, is designed to "accomplish a nearly even temperature distribution in the casing. A nearly even temperature profile within the casing results in more uniform heat distribution within the formation to be heated." Col. 5, lines 47-51. Thus, the lower temperature differential in Mikus refers to the even temperature profile within the well casing as measured from top to bottom. Since the heater in Mikus produces an even temperature profile, it would not be obvious to substitute it for the low temperature differential heater in Ruhl which still would have a non-uniform temperature profile as discussed above.

The position stated on page 31 of the current Office Action "that once a heater has been used for an endothermic process and proven to be an improvement over heaters using flames, it would have been obvious to one skilled in the art at the time of the invention to use said

heater in place of heaters using flames in any other endothermic process" is believed to be untenable for several reasons.

1. One skilled in the art would know that the endothermic chemical reaction (in-situ pyrolysis of hydrocarbons in an underground formation) to which heat is incidentally provided in Mikus, has much lower rate of heat flux requirements than endothermic chemical reactions, such as steam methane reforming, conducted in an above-ground reactor, since the latter involve flowing process streams which rapidly carry heat away from the reactor. Therefore, it would not be obvious to one skilled in the art to use the heater of Mikus in place of a flame-type heater in "any other endothermic process", particularly when such endothermic process requires a far greater heat flux than the 375 watts/foot rate of heat flux produced by the heater in Mikus.

2. One skilled in the art conducting an endothermic chemical reaction in an above-ground reactor is interested in providing sufficient heat in to the chemical reaction to complete the reaction. Thus, it would not be obvious to one skilled in the art to substitute the heater of Mikus for a flame-type heater in "any other endothermic process", unless there was a reasonable expectation such substitution would provide sufficient heat to complete the endothermic chemical process. Mikus only discloses that the thermal conduction could result in pyrolysis of hydrocarbons in-situ, and that some lower molecular weight products could be produced. This does not create a reasonable expectation that substitution of the heater in Mikus for a flame-type heater would provide sufficient heat to complete the quite different type of endothermic chemical reactions of interest to Ruhl and Applicant. Therefore, such substitution would not be obvious.

3. One skilled in the art reading Mikus would recognize the heater in Mikus produces a uniform or even temperature distribution along the portion of the heater that is in the formation. Therefore, one skilled in the art would not attempt to replace a flame-type heater requiring an uneven temperature distribution (i.e., lower temperature at the ends of the combustion tube to permit the use of low temperature seals) with the heater in Mikus, since the Mikus heater produces an even temperature distribution.

Applicant disagrees with the statement on page 31 of the current Office action that the motivation to replace the heater in Ruhl with the heater in Mikus is found in the references themselves. The teachings of the references must be considered in their entirety. While certain teachings in Mikus, for example that a elimination of a flame eliminates hot spots within the burner and surrounding structures, might provide some motivation to replace the heater in Ruhl with the heater in Mikus, other considerations such as Ruhl's requirement for an uneven temperature distribution to permit the use of low temperature seals, and the fact that the

endothermic chemical reactions of interest to Ruhl require an order of magnitude greater heat flux than produced by the heater in Mikus, far outweigh any potential benefits of hot spot elimination in the burner or in the catalyst bed to prolong catalyst life. One skilled in the art is not going to replace the heater in Ruhl with the heater in Mikus to eliminate hot spots or to allow construction with less expensive materials, if the replacement heater does not produce a sufficient rate of heat flux to complete the chemical reactions of interest to Ruhl, or if such replacement is going to necessitate a substantial redesign of the reactor and not allow the use of low temperature seals. Viewed in their entirety, the references do not provide motivation for the replacement of the Ruhl heater with the Mikus heater. The reasons for not making such replacement far outweigh any reasons for making such replacement.

Conclusion

For all the foregoing reasons and in view of the amendments and Dr. Mikus' affidavit, it is believed that the claims now in the application (claims 1-7, 14-18 and 20-24) are patentable. Accordingly, it is respectfully requested that these claims be allowed, and the application be passed to issue.

Respectfully submitted,

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